EFFECT OF WATER TO CEMENT RATIO TO THE MECHANICAL PROPERTIES OF OIL PALM SHELL LIGHTWEIGHT CONCRETE

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ABSTRACT

Oil palm shell (OPS) is a waste material that is obtained by crushing the palm nut in the palm oil mills during the extraction of palm oil. Replacing coarse aggregate with OPS in concrete is one of the way to optimize the use of natural waste material. In this research, crushed OPS was used to replace the coarse aggregate in the production of lightweight aggregate concrete (LWAC). Various water to cement ratio was also used in this research to investigate the effect of water to cement ratio to the mechanical properties of OPS lightweight concrete. The compressive strength, splitting tensile strength, flexural strength and static modulus elasticity test were conducted. The effect of the research was studied at 7 days and 28 days. The test result showed that higher water to cement ratio gives lowest strength to the concrete. Through the results, OPS have been found useful in replaced the coarse aggregate in concrete. However, the water to cement ratio greatly affect the behaviour of OPS lightweight aggregate concrete.

ABSTRAK

Kulit kelapa sawit adalah bahan buangan yang diperolehi dengan menghancurkan biji sawit di kilang-kilang minyak sawit semasa pengekstrakan minyak sawit. Menggantikan agregat kasar dengan kulit kelapa sawit dalam konkrit adalah salah satu cara untuk mengoptimumkan penggunaan bahan buangan semula jadi. Dalam kajian ini, kulit kelapa sawit dihancurkan dan digunakan untuk menggantikan agregat kasar dalam penghasilan konkrit dengan agregat yang ringan. Air dengan simen yg mempunyai pelbagai nisbah juga digunakan dalam kajian ini untuk mengkaji kesan air kepada sifat mekanik konkrit dengan kulit kelapa sawit beragregat ringan. Kekuatan mampatan, kekuatan memecah regangan, kekuatan lenturan dan ujian modulus elastik telah dijalankan. Kesan daripada penyelidikan yang telah dikaji pada 7 hari dan 28 hari. Keputusan ujian menunjukkan bahawa air nisbah simen yang lebih tinggi memberi kekuatan terendah untuk konkrit. Melalui keputusan yang telah didapati, kulit kelapa sawit telah ditemui berguna dalam menggantikan agregat kasar dalam konkrit. Walau bagaimanapun, air nisbah simen juga banyak memberi kesan kepada sifat konkrit beragregat ringan.

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σ	Stress
E	Modulus of Elasticity

LIST OF ABBREVIATIONS

LWA	Lightweight Aggregate
LWC	Lightweight Concrete
NWA	Normalweight Concrete
OPC	Ordinary Portland Cement
OPS	Oil Palm Shell
OPSC	Oil Palm Shell Concrete

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

Since today, researchers vigorously seek an invention to the concrete. One of them was using oil palm shell as a replacement of coarse aggregate in concrete. Oil palm shell (OPS) is a waste material that was obtains by crushing the palm nut in the palm oil mills during the extraction of palm oil. It can be found abundantly in South East Asia and Africa. OPS have been used as lightweight aggregates (LWAs) to produce a lightweight concrete (LWC) which is called oil palm shell lightweight aggregate concrete (OPSC) and many researchers has been working in this area. In the recent investigation, it shows that the use of crushed OPS in a concrete can produced medium and high strength concrete (U. Johnson Alengaram et al., 2013). The use industrial waste material helps to produce a sustainable material. An OPS has a better impact resistance compared to the normal weight aggregate (J. L. Clarke, 2005).

1.1 PROBLEM STATEMENT

This research is done to investigate the effects of water to cement ratio to the mechanical properties of oil palm shell lightweight concrete where the oil palm shell is used to replace the coarse aggregate used in the concrete. Various natural waste materials can be used in our surrounding. Therefore, many researchers have proposed many ways to maximize the use natural waste materials into useful things and one of them is replacing the OPS as coarse aggregate in a concrete. The types of materials used give different results either high or low strength. In this research, replacing oil palm shell in a concrete can identify the mechanical properties with different water to cement ratio used.

1.2 RESEARCH OBJECTIVE

The objectives of this research are:

i. To investigate the effects of water to cement ratio to the mechanical properties of oil palm shell lightweight aggregate concrete.
ii. To determine the optimum water to cement ratio used for the production of the oil palm shell lightweight aggregate concrete.

1.3 SCOPE OF STUDY

The scopes of this study are:

i. Type of concrete grade: 20 N/mm2
ii. Type of concrete: Oil palm shell lightweight aggregate concrete
iii. Percentage of coarse aggregate replacement to OPS aggregate: 100%
iv. Specimens: Cube (width= 100 mm, length= 100 mm, height= 100 mm)
: Cylinder (diameter= 150 mm, height= 300 mm)
: Prism (width= 100 mm, height= 100 mm, length= 350 mm)
v. Type of tests: Compressive Strength Test
: Splitting Tensile Strength Test
: Flexural Strength Test
: Elastic Modulus Elasticity Test

CHAPTER 2

LITERATURE REVIEW

2.0 INTRODUCTION

Concrete is an important material used in the construction industry. It contains of hydraulic cement, water and aggregates. In a concrete, aggregates occupies nearly 60%-80% from concrete volume. The aggregates can be classified as coarse aggregates (with particle size more than 4.75 mm) and fine aggregates (with particle size less than 4.75 mm). Those aggregates are either obtained from natural sources or manufactured. Normally, concrete can be classified into normal concrete and lightweight concrete. These concretes are explained in further sections.

2.1 CONCRETE CLASSIFICATION

2.1.1 Normal concrete

Normal weight concrete known as the concrete contains common compositions of aggregates, water and cement. It has a setting time of 30 - 90 minutes depending upon moisture in atmosphere, fineness of cement. The development of the concrete strength usually starts after 7 days where the common strength value is 10 MPa (1450 psi) to 40 MPa (5800 psi). At 28 days, 75 - 80% of the concrete total strength is attained. Some of the properties for normal concrete are it is strong in compression and weak in tension, having air content of 1 - 2 % and it is not durable against severe conditions e.g. freezing and thawing.

2.1.2 Lightweight concrete

For structures such as multi-stored buildings, it is desirable to reduce the dead loads. Lightweight concrete (LWC) is most suitable for such construction works. It is best produced by entraining air in the cement concrete and can be obtained by anyone of the following methods which are by making concrete with cement and coarse aggregate only. Sometimes, such as concrete is referred to as no-fines concrete. Suitable aggregates are natural aggregate, blast furnace slag, clinker, foamed slag, etc. Since fine aggregates are not used, voids will be created the concrete produced will be a lightweight concrete. Second is by replacing coarse aggregate by porous or cellular aggregate. Some of the advantages and disadvantages of a lightweight concrete are shown in Table 2.1.

Table 2.1: Advantages and disadvantages of lightweight concrete

Advantages	**Disadvantages**
Rapid and relatively simple construction.	Mixtures very sensitive with water content.
Significant reduction of overall weight results in saving structural frames, footing or piles	Mixing time is longer than conventional concrete to assure proper mixing.
Economical in terms of transportation as well as reduction in manpower.	Difficult to place and finish because of the porosity and angularity of the aggregate.

2.2 LIGHTWEIGHT AGGREGATE

Lightweight aggregate is a type of coarse aggregate that is used in the production of lightweight concrete products such as concrete block, structural concrete, and pavement. The lightweight aggregate (LWA) is often used compared to the normal weight aggregate (NWA) because it is more economical and it has more advantages than the normal weight aggregate. Moreover, lightweight aggregate also controls settlements; reduce live loads in formwork and increases stability. In this research, oil palm shell (OPS) will be used as a coarse aggregate with different water to cement ratio as the lightweight aggregate. Table 2.2 shows the advantages and disadvantages of lightweight aggregate.

Table 2.2: Advantages and disadvantages of lightweight aggregate

Advantages	**Disadvantages**
Improved thermal properties.	Inability to provide consistent compressive strengths and density throughout the entire area.
Savings in transporting and handling precast units on site.	
Improved fire resistance.	

An important feature of lightweight aggregate concrete is the good bond between the aggregate and the surrounding hydrated cement paste. This is the consequence of several factors. First, the rough surface texture of many lightweight aggregates is conducive to a good mechanical interlocking between the two materials. In fact, there is often some penetration of cement paste into the open surface pores in the coarse aggregate particles. Second, the moduli of elasticity of the lightweight aggregate particles and of the hardened cement paste do not differ much from one another (Neville, 1995). Besides that, lightweight aggregates are light due to the inclusion of air voids and it follows that they are absorbent, expect for the very few with sealed cells. Most lightweight aggregates are manufactured and hence are, by careful production control, uniform and consistent, which is important to mixing, placing and compaction (J. L. Clarke, 1993).

There are two types of lightweight aggregate which are natural and manufactured lightweight aggregate. Natural lightweight aggregate materials are prepared by crushing and sizing natural rock materials such as pumice, breccia, and volcanic cinders while manufactured lightweight aggregates are prepared by pyro processing shale, clay, or slate in rotary kilns or on traveling grate sintering machines.

2.3 OIL PALM SHELL

Oil palm shell (OPS) is a waste product at the time of extracting oil from oil palm tree (Okpala DC, 1990). Oil palm tree, being as in the same genera as Coconut palm tree, shares many features with it. Its scientific name is Elaeis guineensis and is found mainly in East Africa (Pantzaris TP, Ahmad MJ, 2001). A sample of OPS aggregates is shown in Figure 1. Normally, OPS aggregates are composed of different shapes as shown in the figure.

Figure 2.1: Oil palm shell

OPS is used as a lightweight aggregate in many construction such as one storey building, foot bridge, floor roofing and water treatment where it is also used as granular filter material (U. Johnson Alengaram, 2013). OPS as a lightweight concrete is having low thermal conductivity and high insulation capacity that may result in low energy consumption and greener environment.

Table 2.3 and Table 2.4 showed the physical and mechanical properties for the oil palm shell aggregate. The mechanical properties of OPS change depending on the physical properties of OPS. The physical properties result is compared with normal weight aggregate on their specific gravity, thickness and shape, surface texture, loose and compacted bulk densities, air and moisture content, water absorption and porosity.

Table 2.3: Physical behavior of OPS aggregate

Author (year)	Specific gravity	Loose bulk density (kg/m3)	Compacted bulk density (kg/m3)	Moisture content (%)	Water absorption , 24h (1h) (%)	Porosity (%)
Abdullah (1984)	–	–	620	–	–	–
Okafor (1988)	1.37	512	589	–	27.3	
Okpala (1990)	1.14	545	595	–	21.3	37
Basri et al. (1999)	1.17	–	592	–	23.32	–
Mannan and Ganapathy (2002)	1.17	–	592	–	23.32	–
Teo et al. (2006)	1.17	500 – 600	–	–	33	–
Ndoke (2006)	1.62	–	740	9	14	28
Jumaat et al. (2008)	1.37	566	620	8 – 15	23.8	–

Table 2.4: Mechanical behavior of OPS aggregate

Author (year)	Abrasion value (Los Angeles)	Aggregate impact value (AIV) (%)	Aggregate crushing value (ACV) (%)
Okafor (1988)	–	6.00	10.00
Okpala (1990)	3.05	–	4.67
Basri et al. (1999)	4.80	–	–
Mannan and Ganapathy (2001, 2002)	4.80	7.86	–
Olanipekun (2005)	3.60	–	–
Mannan et al. (2006)	–	1.04 – 7.86	–
Ndoke (2006)	–	4.50	–
Teo et al. (2006 and 2007)	4.90	7.51	8.00
Jumaat et al. (2008)	8.02	3.91	–
Mahmud et al. (2009)	–	3.91	–

Source: U. Johnson Alengaram et al., 2013

The physical properties of OPS and crushed stone aggregate are illustrated in Table 2.5. From the table, the crushed stone aggregate has the highest value in most of the properties. The palm shell aggregate is higher than crushed stone aggregate in only one properties based on the table which is in water absorption for 24 hour (%) with 25.64 % compared to crushed stone aggregate with 0.7 %.

Table 2.5: Properties of OPS and crushed stone aggregate

Properties	Palm shell aggregate	Crushed stone aggregate
Specific gravity	1.21	2.72
Bulk density (Kg/m^3)	572	1445
Los Angles abrasion value, %	5.1	24.5
Water absorption for 24 h (%)	25.64	0.7
Aggregate crushing value	6.78	17.92
Aggregate impact value	6.65	12.32
Fineness modulus	6.24	6.76
Shell thickness, mm	0.5–4.0	5–20
Maximum aggregate size, mm	12.5	20

2.3.1 Mechanical Properties of OPS

2.3.1.1 Compressive strength

The compressive strength value is different depending on the mix design and curing conditions of the oil palm shell concrete. One of the experiments done is using OPS as lightweight aggregate and has achieved compressive strength up to 20 MPa with the w/c ratio of 0.4 (Abdullah AAA, 1997). It is almost equal to the value of the specified cylindrical compressive strength (fc) of 17 MPa. Generally, it can be seen from the experiment that the mechanical properties of oil palm shell concrete increased with decreasing w/c ratio. In addition, the probability of making steel fiber and high strength lightweight concrete (HSLWC) with crushed OPS is also investigated. As the result, they have achieved 28-day compressive strength in the range of 41–45 MPa with steel fibers but however, they achieved 28-day compressive strength of up to 48 MPa with crushed OPS and lime stone powder as filler (Shafigh P et al., 2011).

2.3.1.2 Splitting tensile strength

The splitting tensile strength also results in different range which is within 2.0-2.4 with different water/cement of 0.65-0.48 (Okafor, 1988). Many researcher reported similar values in the splitting tensile strength test and these values are about 6–10% of their respective compressive strengths. The splitting tensile strength is also depends on the curing condition and physical strength of oil palm shell (Mannan and Ganapathy, 2002).

2.3.1.3 Modulus of Elasticity

Using other lightweight aggregate concrete, the static modulus of elasticity of other LWAC varies in the range of 7.69-11.4 GPa depends on the mix design and time of curing. The results show that the E-values are quite similar to other lightweight aggregate concrete (Hossain A et al., 2010). When fine aggregate content is increased with subsequent reduction in OPKS, the higher the E-values compared to the concrete with high OPS content (Alengaram et al., 2011).

2.3.2 TYPES OF LIGHTWEIGHT AGGREGATE

2.3.2.1 Coconut Shell

Coconut shell is another type of replacement of aggregate used in the concrete. It is an agricultural biodegradable waste which is becoming popular nowadays because it is easy to hand and has low dead loads. By using coconut shell, it helps the prevention of deforestation and it is less expensive. The husk of a coconut comprises 30 per cent coconut fibers and 70 percent flesh (Bharati Vidyapeeth Deemed, 2013). Figure 2.2 shows the picture of coconut shell.

Figure 2.2: Coconut shell

2.3.2.2 Cockle Shell

Cockles are marine bivalve molluscs which act as an important source of protein in the South East Asian region. It has lead towards the generation of abundant waste shell and it can be seen that the shells is dumped and left untreated which cause unpleasant smell that is disturbing the view of the surrounding (Boey et al, 2011). As the cockle's production is increasing, the cockles shell waste also would be in a higher amount which has leads the effort of treating the waste cockles shell as one of the ingredient in mixing the concrete. At the same time, this alternative can be used to preserve the natural coarse aggregate for the use of future generation. Figure 2.3 shows the example of cockle shell.

Figure 2.3: Cockle shell

2.3.2.3 Pumice

Pumice is a super cooled liquid which formed when the molten SiO2 rich lava from the explosive eruption of a volcano cools. It has low density due to the presence of the bubbles. The mixing of pumice into concrete has provided the structural strength and insulation for the concrete. It can be found in many parts of the world where volcanoes are present. It has been used as a lightweight aggregate in concrete due to its toughness and durability that has no reaction with any of the ingredients of concrete and steel. Enough cement is used to coat and bind the aggregate together. Figure 2.4 shows an example of pumice.

Figure 2.4: Pumice

2.4 WATER/CEMENT RATIO

The water/cement ratio (w/c) is one of the major factors but not only the one influencing the strength of concrete. It is responsible mainly for the porosity of the hardened cement paste. Water/cement ratio is the water used to the quantum of cement in the mixture by weight. For proper workability, the water/cement ratio varies from 0.4 to 0.6. However, maximum strength is derived at water/ cement is 0.4. When it is decreased to less than 0.4, there is improper consistency and workability of cement and honeycombed structure. However, concrete compacted by vibrator displays higher strength even up to water/cement = 0.3. At water/cement ratio more than 0.4, the expansion of cement on hydration is insufficient to occupy the space previously filled with water. Hence, the porosity increases and strength decreases. In arriving at the water/cement values it is assumed that aggregates are saturated with the surfaces in dry condition. Suitable adjustments should be made for dry aggregates.

Table 2.6 indicates the results of the target compressive strength and the result that the researchers obtained after the test using different water to cement ratio. Most of the researchers succeeded in achieving their target strength. However, only Mannan and Ganapthay failed in achieving the target strength.

Table 2.6: Results of the target compressive strength and the result that the researchers obtained after the test using different water to cement ratio

Author/ Year	**W/C Ratio**	**Compressive Strength, MPa**	**Result**
Olanipekun et. al. (2006)	0.5	15	27.5
Teo et. al. (2006)	0.4	17	28.1
Olanipekun et. al. (2005)	0.50	17	22.97
Mannan and Ganapthay (2002)	0.50	25	14.40
Mannan and Ganapthay (2001)	0.60	25	11.80
Mannan and Ganapthay (2001)	0.53	28	13.65
U. Johnson Alengaram et. al. (2010)	0.41	30	37
Mahmud, H. et. al. (2009)	0.35	35	28-38

2.5 COMPARISON OF OPS WITH OTHER AGRICULTURAL WASTE

Comparison of density and strength of oil palm shell and concrete with other agricultural wastes such as oil palm clinkers, rice husk and coconut shells as coarse aggregates was done by Abdullah. From the experimental test results, he concluded that concrete made with rice husk had the lowest bulk density with 136 kg/m3 and the lowest compressive and tensile strengths. Concrete made with oil palm clinker showed the highest bulk density and 28-day compressive and tensile strengths. The 28-day compressive strength of oil palm shell with a density of 620 kg/m3 of 17.4 MPa was found lower than the concrete made with oil palm clinker that produced 29.8 MPa. Gunasekaran et al. showed that water absorption, specific gravity, impact value and bulk density of coconut shell aggregate was comparable to those of oil palm shell. The 28-day compressive strength of coconut shell concrete was found to be in the range of 5–27 MPa; however with a slump of only 5 mm, the coconut shell concrete exhibited a very poor workability. Moreover, the compressive strength, modulus of rupture, splitting tensile strength, theoretical and experimental bond strength performed on coconut shell concrete were comparable to oil palm shell. The graph of comparison of the compressive strength with types of aggregate is shown in Figure 2.5.

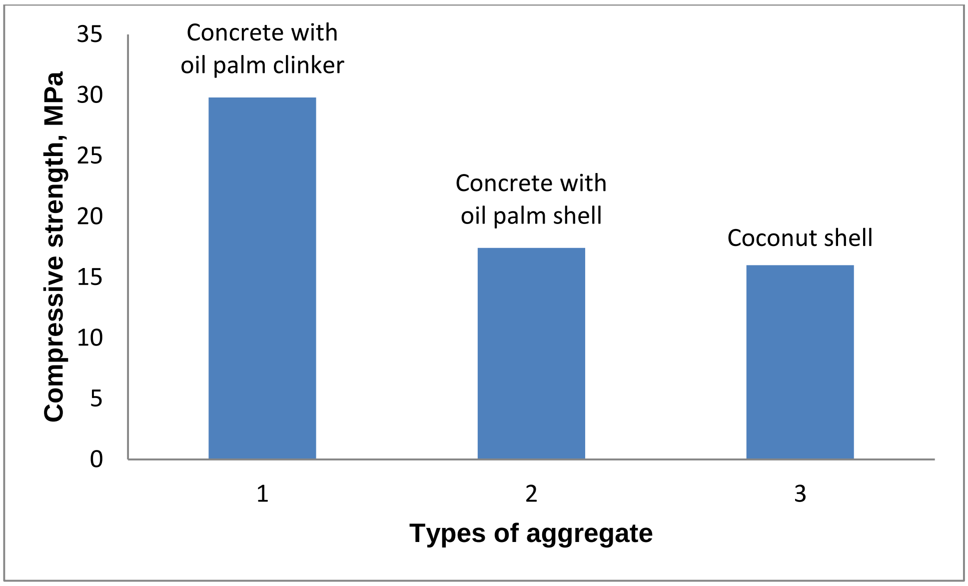

Figure 2.5: Relationship between the compressive strength and types of aggregate

2.6 SUMMARY

Water to cement ratio is one of the crucial things that affect the mechanical properties of the concrete. The result achieved is also depending on the characteristic of the material used in the concrete production. So, water to cement ratio and the type of materials used must be chosen wisely to get a better result. From the previous research,